FingerDOS: A Fingerprint Database Based on Optical Sensor

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Abstract: - Fingerprint image acquisition is known to be a challenging aspect in fingerprint recognition. Many fingerprint databases were developed in conjunction with the growth of fingerprint algorithms. However, some of the databases are not publicly available, or insufficient number of samples provided, or having inconsistent fingerprint images. The purpose of this study is to present a new fingerprint database based on optical sensor. The main feature of this database is that the displacement of finger on the sensor plate is kept minimum. This is to provide additional test platform for fingerprint recognition algorithm whereby less attention is given for displaced finger, and more focus on the ability to recognize complete fingerprints. There are 3600 fingerprint images acquired from 60 subjects. Each of the subjects contributed 60 fingerprint images of his six fingers (thumb, index finger and middle finger for left and right hands). In this paper, the acquisition protocols are outlined and the content of the database are described. This database is then compared with other existing online fingerprint database and a list of the characteristics of the databases is summarized. In comparison, our database has more number of fingerprint samples with minimal displaced finger. Request for the database is available at http://www.fingerdos.wordpress.com.

Key-Words: - Fingerprint database, biometric, optical sensor.

1 Introduction

Biometric identification had existed since hundreds of years ago. Human started to look into something that can prove one's identity. When the fingerprint marks left on handmade clays were found in China, the study of fingerprint began to emerge. The usage of handprint as an evidence for document validity led to more fingerprint studies. During this period, the collection of fingerprint images has not started. Sir William Herschel, a British officer in India who was doing researches on fingerprint, claimed that fingerprint can be used as individuality [1]. He started to collect fingerprints from his family and friends and use them in his research. As many researchers have foreseen the potential of fingerprint as person identification, more and more studies have been done on fingerprints. In 1892, Galton established his first book on fingerprint entitled Finger Prints. In this book, Galton explained about fingerprint patterns which is called as Galton Details. Galton Details described three types of fingerprint patterns, i.e., loop, arch and whorl [2].

The uniqueness of fingerprint has helped to solve a murder case in 1892, in Buenos Aires, Argentina, which involved a woman named Rojas who murdered her two children. The case had been solved when Alvarez, an inspector discovered a bloody fingerprint on the bedroom door. This was the first murder case which used fingerprint as evidence to prove that the murderer was guilty [3]. This case shows that fingerprint has the potential for personal identification. In 1902, fingerprint started to be used as evidence in the courts of England. The United State Government began to collect fingerprints in 1904 to create fingerprint database. Since then, fingerprint databases have grown larger.

At the earlier stage of fingerprint identification, manual approaches were performed to identify one's fingerprint. The database was organized according to some specific fingerprint classifications, e.g. National Crime Information Centre (NCIC) Classification and Royal Canadian Mounted Police (RCMP) Henry Classification [4]. The Federal Bureau of Investigation (FBI) found that, these approaches were time consuming and it was getting difficult to conduct identification as the fingerprint database was getting larger. A new method was then introduced which involves computer automation in 1950s.

Automated Fingerprint Identification System (AFIS) [5] is one of the earliest identification system involving the use of computer automation. The automated system was needed to extract each fingerprint image and process each of the images into a smaller template. Apart from that, the system was also used to automatically search for a fingerprint match in a reduced list of probable candidates. AFIS is based on comparing minutiae on fingerprint ridges. The same method for fingerprint identification is still in use today.

Although AFIS has solved the manual fingerprint matching issue, automatic fingerprint algorithms are not as accurate as manual matching by forensic experts [6]. The system has difficulty in tracing a small part of a fingerprint and dealing with many noise sources in the fingerprint image. In order to improve the current matching system, many researchers have started to create new algorithms or make changes in their old algorithms. To test the accuracy of the algorithms, they usually acquire their own fingerprint database.

The issue of algorithms testing with only their own database is, one does not know whether the algorithms perform better or worse on other fingerprint databases. Getting a good recognition rate in a single database does not mean it will have the same performance on other fingerprint databases. Therefore, testing the algorithms on multiple fingerprint databases is important in order to ensure the credibility of the algorithms.

In the past few years, many fingerprint databases have been created for the purpose of algorithm testing. One of the largest databases is from the National Institute of Standards and Technology (NIST) Fingerprint Database. The database is named as Special Database and consists of various versions. Some other databases are Chinese Academy of Sciences' Institute of Automation (CASIA) Fingerprint V5 Database [7], Fingerprint Verification Competition Databases (FVC) [8, 9, 10, 11], Spanish Ministry of Science and Technology (MCYT) Fingerprint Corpus [12], and etc. These databases were acquired with different types of fingerprint sensors in different settings. Even though many of the databases involve hundreds of subjects during the acquisition process, however, some of the databases contain no more than 5 fingerprint samples for each finger.

In this paper, a Fingerprint Database Based on Optical Sensor (FingerDOS) is presented. Section 2 explains related works with our database. Section 3 describes our fingerprint database and the acquisition protocols involve in the fingerprint collection. Comparison of our database with other existing databases is then explained in Section 4. After the potential uses of FingerDOS are presented, conclusions are then drawn in Section 5.

2 Related Works

In the last few years, researchers were getting interested in fingerprint based biometric system. Many algorithms were developed and different techniques were discovered for fingerprint recognition. Since public availability for fingerprint databases is quite limited, researchers collect fingerprints by themselves to perform test on their algorithms. They used different types of sensors in fingerprint image acquisition, i.e., capacitive sensor, optical sensor, inked fingerprint, etc. The problem with this kind of approaches is, they cannot compare their result with others in term of performance and recognition rate.

Understand the needs for a benchmark fingerprint database, many researchers and industries produced fingerprint database and made the database available. Some examples are CASIA Fingerprint V5 Database, FVC Fingerprint Database, MCYT Baseline Corpus, and BioSecure Multimodal Database [13]. Among all these databases, only CASIA Fingerprint V5 is available for public to download without charges. For FVCs, the complete database can be obtained by purchasing the second edition of the published book [14], which included a DVD containing the full databases.

CASIA database includes eight fingerprints, i.e., thumb, index, middle, and ring fingers from both hands. Five samples per finger were collected from a total of 500 subjects. The fingerprint images were captured in one session using an optical scanner. The subjects have to rotate their fingers and put various levels of pressure to generate significant intra-class variation.

There are several versions of FVC Fingerprint Database, i.e., FVC2000, FVC2002, FVC2004, and FVC2006. Each year, four different databases were collected. In FVC2000, FVC2002 and FVC2004, two optical sensors, a capacitive sensor and a synthetic fingerprint generation were used to collect the fingerprints. In FVC2006, electric field sensor, optical sensor, thermal sweeping sensor and synthetic fingerprint generation were used. A total of 90 subjects were randomly partitioned into three groups, i.e., 30 subjects in a group for each sensor. Eight fingerprint samples per finger were captured in FVC2000, and 12 in FVC2002, FVC2004, and FVC2006.

The MYCT Fingerprint Corpus is a part of MYCT Baseline Corpus which is a bimodal database, i.e., fingerprint and signature. Twelve fingerprint samples per finger were acquired from 330 subjects for all the ten fingers. Optical and capacitive sensors were used to capture the fingerprints. Three different control levels were set to create varieties in the fingerprint images.

Fingerprint optical sensor is a common device used to capture fingerprints. It is believed that, fingerprint images acquired from an optical sensor has a better performance in fingerprint matching [15, 16]. There are several fingerprint databases which have been collected by previous researchers and industries. However, only some are available for the public to use. Besides, number of sample taken per fingerprint is limited. As for example, in CASIA, there are only five samples per finger, which is insufficient for effective testing.

Our database, FingerDOS, contains 10 samples per finger with minimized finger displacement on the sensor plate. Consistency in image acquisition process helps to overcome the difficultness of the data processing algorithms and improves accurateness in image recognition [17]. By providing more samples per finger, more samples are available to be used for testing. One of the important factors in acquiring more number of samples is, to obtain a reliable estimate of error rates [18]. The larger the test sample size, more reliable is the test result [19, 20].

3 FingerDOS Description

The main idea of designing this fingerprint database is to (1) create fingerprint images with minimized finger displacement on sensor plate, (2) provide more samples per finger and (3) develop more fingerprint database available for researches. In this section, description of FingerDOS and the database collection methods are presented. FingerDOS contains 3600 fingerprint images from 60 subjects. Each of the fingerprint images is saved in 256 gray-level bitmap image file (bmp). An optical sensor was used to capture the fingerprint, i.e., SecuGen iD-USB SC. The average age of the subjects is 22 years old. They are from multiple ethnics. 56% of the subjects are male and 44% are females.

The fingerprint database was collected from two separate acquisition sessions. The collecting process was guided by a supervisor so that the database was conformed to the acquisition protocol. In order to ensure all the data were valid, all the fingerprint samples were manually verified by human. Any invalid data such as unclear or wrongly labeled fingerprint images were discarded, and new images were captured and kept. The acquisition protocols are further described in the following subsections.

3.1 Laboratory Setting

The laboratory setting for all sessions were ensured to be the same. It was a closed air-conditioned laboratory with sufficient lighting condition. An adjustable chair was provided for the subjects. They were asked to sit as comfortable as they preferred. The fingerprint acquisition took around 5-10 minutes for each of the subjects.

3.2 Fingerprint Sensor

An optical sensor was used to collect the fingerprint images, which is SecuGen iD-USB SC.Table 1 shows the specifications of the sensor.

Table 1 Sensor specifications [21]

Specification	SecuGen iD-USB SC
Image resolution	500 DPI
Image size	260 x 300 pixels
Platen size	16.1mm x 18.2mm
Effective sensing area	13.2mm x 15.2mm
Image greyscale	256 levels (8 bit)
Light source/typical lifetime	Red LED/60000 hours
Fingerprint capture time	0.2~0.5 second with Smart Capture

3.3 Fingerprint Acquisition

There were six fingers used in the fingerprints acquisition, i.e., thumb, index finger and middle finger for both right and left hands of the subject. Ten samples were captured for each finger. One subject contributed a total of 60 fingerprint images. Fig. 1 shows a sample of thumb, index finger and middle finger captured during the acquisition process.

Fig. 1. Fingerprint samples captured using SecuGen iD-USB SC

All the fingerprint images were captured with minimal displacement and rotations. The sensor produced 77.2kb size per image. The sensor plate was cleaned only if there was any residue left on it while capturing the fingerprint. The subjects' fingers were wiped by using a dry tissue to clean it from any dirt and excessive sweat prior to the fingerprint acquisition.

3.4 Validation Process

Validation process was done by referring to [22]. There are two concepts that are counted, i.e., invalid sample and low quality sample. According to [22], invalid sample is a sample that does not comply with the specification (e.g. thumb labelled as the middle finger, fingerprint images for subject one labelled as subject two, etc.). Meanwhile, low quality sample is defined as a sample that will perform badly on recognition system (e.g. very dry fingerprint image, wet fingerprint image, etc.).

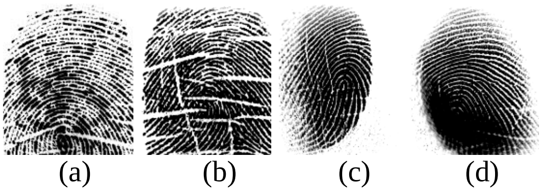

Fig. 2. Example of low quality fingerprint images

Fig. 2 shows some examples for low quality fingerprint images. Fig. 2(a) is obtained from a dry fingertip which causes a very noisy image. Worn ridge structure causes unwanted lines on the fingerprint image as shown in Fig. 2(b). This kind of problem affects the recognition as it increases the potential of missed identification. Uneven pressure finger on the sensor plate generates partially image which causes missing on some part of the image as illustrated in Fig. 2(c). Wet or sweaty fingertip causes a very dark appearance in the captured image which is barely recognized. An example of this problem is shown in Fig. 2(d).

Fig. 3. Example of rejected fingerprint images

The main purpose of this database is to create a fingerprint database with minimized finger displacement and higher quality images. Images with higher quality help to improve the performance of the recognition algorithms [23]. However, not all the low quality images were rejected during the acquisition. Only images with a very low quality, in other words, very bad images were rejected. The image is classified as bad image when it is heavily corrupted that even basic ridge or valley information can hardly be identified [14]. Fig. 3 shows rejected fingerprint images which caused by improper finger placed on the sensor plate and when the subject removes his finger too fast before it is captured.

4 Comparison with Other Databases

Many fingerprint databases were collected by past researchers and industries. Most of the fingerprint images were randomly scanned to create varieties in the databases. One of the largest biometric databases in the world was collected by the Federal Bureau of Investigation (FBI). Their database is known as Integrated Automated Fingerprint Identification System (IAFIS), which includes 73000 known and suspected terrorists' fingerprints [24]. However this database is not available to the public for research purposes. Another well-known large database is NIST database, but it is not well suited for the evaluation of algorithms operating with live-scan images. According to [14], some of the databases in NIST consist of rolled inked impressions on cards images, which are dissimilar from live-scan images.

One of the potential uses of our database is for beginners to conduct research on fingerprints. It is known that fingerprint images with lots of noise and displacement made them hard to be recognized. Therefore, the produced recognition rate is lower and time taken to process the images is longer [25, 26]. Most of the current fingerprint databases have different finger position, brightness, error, and displacement. For that reason, this fingerprint database is created to provide fingerprint images with consistent position, larger size of fingerprint covered on the sensor plate, and minimized finger displacement. The next section describes other fingerprint databases which are freely available to the public. However, FVCs only provide samples for public to use. A short description of the databases are explained and then compared with our database.

4.1 CASIA Fingerprint Image Database Version 5.0

CASIA Fingerprint Image Database Version 5.0 or also known as CASIA-FingerprintV5 is a fingerprint database provided by Biometrics Ideal Test. All the images were captured using an optical fingerprint sensor, i.e., URU4000. CASIA-FingerprintV5 contains 20000 fingerprint images of 500 subjects. Each subject contributed 40 fingerprint images of his eight fingers, i.e., thumb, index finger, middle finger and ring finger for both hands. Five images per finger were captured. Various levels of pressure were applied during the fingerprints acquisition.

Fig. 4. Image samples from CASIA-FingerprintV5

Fig. 4 shows some samples of fingerprint images in CASIA-FingerprintV5. It is shown that there are five different position of the finger on the sensor plate. According to [7], the purpose of capturing the fingerprints in this way is to generate intra-class variations.

4.2 Fingerprint Verification Competition 2000, 2002, 2004 and 2006

There are four different databases created in each of the FVCs, i.e., Database 1 (DB1), Database 2 (DB2), Database 3 (DB3), and Database 4 (DB4). These databases were collected using different type of sensors. Fig. 5 shows image samples taken from each database in FVC2000, FVC2002, FVC2004, and FVC2006 respectively.

In FVC2000, DB1 and DB2 were collected using a small size and low cost optical and capacitive sensors. DB3 was captured using a larger size and higher quality optical sensor. There were 110 different fingers involved in the fingerprint image acquisition. Each set of the four databases consist of 32 fingerprint images from four fingers, i.e., index finger and middle finger from both hands. For DB4, it was synthetically generated using a Synthetic Fingerprint Generation or also known as SFinGe [14]. There were no specific instructions given to the subjects during the fingerprint acquisition. Fig. 5(a) shows some samples of fingerprint images collected in FVC2000. The position of the finger on the sensor plate was not synchronized. The resolution of the images is about 500dpi.

FVC2002 created another four fingerprint databases, i.e., DB1, DB2, DB3, and DB4. DB1 and DB2 were collected by using two optical sensors, DB3 by using capacitive sensor and DB4 was generated using SFinGe. A total of 90 subjects volunteered in the fingerprint acquisition, which were then partitioned into three groups of equal number of subjects. Two fingers (i.e., index and middle fingers) from both hands with 12 impressions per finger were acquired. Image samples from FVC2002 are shown in Fig. 5 (b) with one sample from DB1, DB2, DB3, and DB4, respectively.

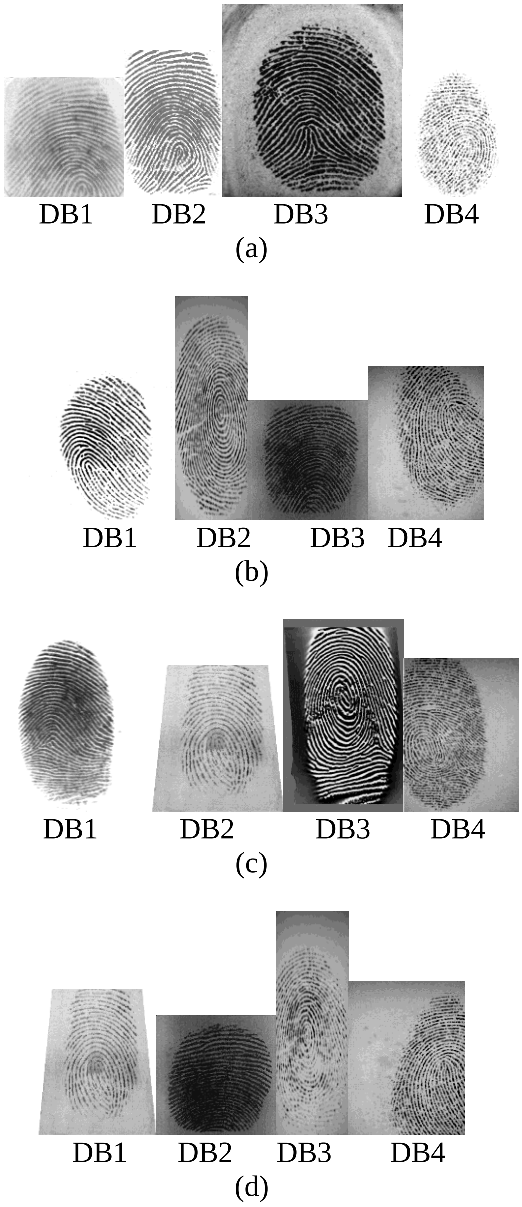

Fig. 5. Image samples from (a) FVC2000, (b) FVC2002, (c) FVC2004 and (d) FVC2006

In FVC2004, a new type of sensor was used, i.e., thermal sweeping sensor. This sensor was used to collect DB3. DB1, DB2, and DB4 still used the same type of fingerprint sensors, i.e., optical sensors and SFinGe. Same like FVC2002, the number of subjects for each group of databases were 30 subjects.

There are some major differences that can be seen in FVC2006 compared to the previous three databases. One of them is the type of sensor used to collect fingerprints for DB1, i.e., electric field sensor. DB2, DB3, and DB4 were collected using optical sensor, thermal sweeping sensor and SFinGe

Table 2 Characteristics of the databases

Name	Sensor Type	Image Size	Resolution	No. of Subject	Total No. of Fingerprint Images	No. of sample per finger	Finger
FingerDOS	Optical sensor	260x300	500dpi	60	3600	10	Thumb, index, middle finger
CASIA-FingerprintV5	Optical sensor	328x356	-	500	20 000	5	Thumb, index, middle, fore finger
FVC2000 DB1	Low cost optical sensor	300x300	500dpi	110 fingers	880	8	Index, middle finger
FVC2000 DB2	Low cost capacitive sensor	256x364	500dpi	110 fingers	880	8	Index, middle finger
FVC2000 DB3	Optical sensor	448x478	500dpi	110 fingers	880	8	Thumb, index, middle finger
FVC2000 DB4	Synthetic Generator	240x320	~500dpi	110 fingers	880	8	Index, middle finger
FVC2002 DB1	Optical Sensor	388x374	500dpi	30	1440	12	Index, middle finger
FVC2002 DB2	Optical Sensor	296x560	569dpi	30	1440	12	Index, middle finger
FVC2002 DB3	Capacitive sensor	300x300	500dpi	30	1440	12	Index, middle finger
FVC2002 DB4	sFinGe v2.51	288x384	~500dpi	110 fingers	1440	12	Index, middle finger
FVC2004 DB1	Optical sensor	640x480	500dpi	30	1440	12	Index, middle finger
FVC2004 DB2	Optical sensor	328x480	500dpi	30	1440	12	Index, middle finger
FVC2004 DB3	Thermal sweeping sensor	300x480	512dpi	30	1440	12	Index, middle finger
FVC2004 DB4	sFinGe v3.0	288x384	~500dpi	110 fingers	1440	12	Index, middle finger
FVC2006 DB1	Electric field sensor	96x96	250dpi	150 fingers	1800	12	-
FVC2006 DB2	Optical sensor	400x560	569dpi	150 fingers	1800	12	-
FVC2006 DB3	Thermal sweeping sensor	400x500	500dpi	150 fingers	1800	12	-
FVC2006 DB4	sFinGe V3.0	288x384	~500dpi	150 fingers	1800	12	-

respectively. There were no strict regulations for the subjects to follow. However, the final datasets were chosen based on the most difficult fingers according to quality index [27].

4.3 Database Comparison

Even though there are many other existing fingerprint databases, these databases differ from one another. Among all the databases as explained in the previous sections, CASIA-FingerprintV5 has the largest number of subjects and fingerprint images. However, there were only five samples per finger for each subject. The FVC has conducted four fingerprint verification competitions in four different years. Each year, they collected four new fingerprint databases. In all four databases, they had collected the same amount of fingerprint images using different type of sensors.

In comparison, our database, i.e., FingerDOS, was acquired using an optical sensor as explained in the previous section. Compared to the other databases, our database has more number of fingerprint samples per finger with minimal finger displacement on the sensor plate. Table 2 gives a number of characteristics for the stated databases.

4 Conclusion

In this paper, a new fingerprint database has been presented. This fingerprint database is using one of the most common fingerprint sensors, i.e., optical sensor. Some of the reasons in using this kind of sensor are because, it is cheaper and produces a better quality of fingerprint images compared to other sensors. There were 60 subjects involved in the acquisition of fingerprint images.

Although there are many other fingerprint databases available publicly, most of them were collected with finger displacement on the sensor plate. The inconsistency made the fingerprints hard to be recognized and causes the recognition rate becomes lower.

One of the advantages of our fingerprint database is, it has less fingerprint displacement which makes it easier to conduct recognition. Besides, this fingerprint database also has a wide number of fingerprint samples, i.e., 10 samples per finger. Online description and request of the database are available to the public at http://www.fingerdos.wordpress.com.

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